

Building & Construction

Putting Safety First: A Look From Yesterday to Tomorrow on the Building of Our Safety Infrastructure

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Research to advance the cause of safety, and its implementation into the world of practitioners, is a noble venture that for the last one hundred years has been shared by the National Institute of Standards and Technology (NIST), the NFPA, and others. We can ably look back today and see a rich history of partnership and progress. It is our task to carry this same history into the future.

The way we interpret safety has changed over the last century, and it is dependant upon society's appreciation for the quality of life. Standardizing safety is a challenge. It inherently incorporates social, political, economic, and legal agendas into our efforts to provide technical conformity.

From Humble Beginnings

In the twilight of the 19th century, innovation and invention were propelling civilization to new dimensions.

Amidst the struggles of the working class and a population being bolstered by newly arriving immigrants, the late 1890's in North America were a time of dramatic change, growth, and opportunity. New technology was erupting everywhere, and it was in the face of great technological advances, or more appropriately the lack of consistency thereof, that a need for codes and standards and their administrating organizations began to solidify.

The year was 1901. Along with witnessing the founding of the National Bureau of Standards* (NBS), it was in general a banner time for codes and standards development. As the new century dawned, several organizations were emerging to join others that today comprise the backbone of the North American safety infrastructure.

The year 1901 saw the oldest standards developing organization in the United States, the U.S. Pharmacopeial Convention, observing their 81st year of service [1]. The ASCE (American Society of Civil Engineers) was preparing for their 50th anniversary celebration,

while the ASME (American Society of Mechanical Engineers) was entering their 21st year. The IEEE (Institute of Electrical and Electronic Engineers) marked their 17th year of existence, and the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) had their 7th following their establishment in 1894. NFPA (National Fire Protection Association) was founded in 1896 and by the year 1901 had already become somewhat prolific with regard to its output of codes and standards. The National Electrical Contractors Association (NECA) was founded in 1901, and ASTM (American Society of Testing and Materials), which traces its founding to 1898, saw the year 1901 as a milestone as their first standard "Structural Steel for Bridges" was approved at their annual meeting.

Product certification practices were also evolving in 1901. This was the year that Underwriters Electrical Bureau, which was established in 1894 by William Henry Merrill, incorporated and changed their name to Underwriters Laboratories, Inc. William Merrill was also an integral participant in NFPA activities in these early days, where he served as the NFPA's Secretary-Treasurer from 1903 to 1908, and as President from 1910 to 1911.

The U.S. Federal Government was challenged during 1901 with the assassination of President McKinley in September. But despite this handicap, among the great achievements of that year was the action by Congress to establish the NBS, to support industry, commerce, scientific institutions, and all branches of government. In this role NBS has ably served as a foundation for progress to advance measurement science and support codes and standards development.

A Case Study in Partnership: The Great Baltimore Fire

It is clear that the safety infrastructure in the United States and elsewhere in the world has benefited significantly by the last century of NIST contributions. Although we can readily find countless examples, one of the earliest and somewhat colorful efforts was that involving the threads of fire hose, and this provides a distinctive illustration of how NIST has contributed directly to advances in safety.

* The National Bureau of Standards (NBS) revised its name to the National Institute of Standards and Technology (NIST) in 1988, and thus NBS and NIST is the same organization mentioned herein.

At the dawn of the 20th century, the industrial age had blossomed to new heights and the growth of urban centers in North America had increased dramatically. The most intense fire safety focus in those early days of the 1900's was less on individual building fire loss, and more on the sweeping conflagrations that would occasionally ravage the burgeoning cities of North America.

From one such conflagration came forth a loud cry for standardization. On Sunday, February 7, 1904, a fire broke out in the basement of the John E. Hurst & Company Building in Baltimore, Maryland. After taking hold of the entire structure, it began leaping from building to building. Before it was over, the fire had burned for more than 30 hours and destroyed approximately 2,500 buildings in an 80-block area located in the heart of the city [2].

The response from afar by the fire service was indeed noble. Apparatus was immediately dispatched by train from as far away as Washington, DC, Philadelphia, and New York to provide desperately needed firefighting reinforcements. Yet each municipality had its own unique threads for their fire hose, and consequently, their hoses could not connect to Baltimore's hydrant system and hoses, and they were forced to watch helplessly as the flames spread.

In the world of safety issues, it often takes a singular dramatic yet unfortunate event to bestow the societal mindset with a conviction to enact change. The lessons learned are typically hard lessons, and this was the case with the Baltimore Fire. Although the fire hose thread problem had been recognized for several years, it wasn't until the Baltimore conflagration that momentum finally solidified to take corrective action.

Shortly after the fire, the NBS received requests from the NFPA and others for assistance in resolving this important issue. As a result, the Bureau began a study of fire hose couplings, and over 600 couplings from across the country were collected and analyzed.

Based on the research provided by NBS, the NFPA adopted as national models in 1905 a standard hose coupling and an interchangeable coupling device for non-standard hoses [3]. Today, that document continues to serve this function as NFPA 1963, Standard for Fire Hose Connections, with requirements that provide a level of uniformity that is a direct factor in combating citywide conflagrations of this type [4].

Lessons in the Value of Human Life

In a world of standards, those dealing with safety go far beyond the spectrum of documents involved with marketplace conformity and trade facilitation.

In contrast, safety documents by their very nature typically restrict trade and freedom, but they do so to safeguard both an individual's safety and society's common good. Such documents can be powerful and far-reaching. All corners of civilization are often directly impacted, and the stakes can be very high. If poorly done, or not effectively implemented, the consequences may be extreme (i.e., serious injury or death).

Knowing that safety documents come in countless variations, it is useful to exemplify what might best be considered as the ultimate end of the safety document spectrum, that being the so-called "Codes." These model documents have traditionally evolved to be the caretakers of the premier societal mindset, and in this sense, they are entrusted with upholding the highest order of protection. Codes are typically written so that they can be adopted directly into law, and to reference numerous other more detailed technical documents. As such, their impact on all of society's constituents tends to be very significant.

When we talk about "safety," exactly what do we mean? We use this word regularly in the codes and standards world, and it has special significance in certain important regulations and agreements (e.g., GATT, General Agreement on Tariffs and Trade). But this is a somewhat elusive term that is relatively fluid, depending on how, when, and where it is applied.

With a focus herein on the field of metrology, one of the more intriguing challenges in the safety arena is that of the value of human life, and the measurement of this value. This may strike the casual observer as a difficult concept to comprehend, but it has been the subject of considerable study. As but one illustration of this point is the chapter in the *SFPE Handbook of Fire Protection Engineering* entitled "Value of Human Life [5]." Incorporating such quantifiable data into risk assessment calculations speaks clearly to what will likely be the norm with our approach to scientifically address safety issues in the future.

The High Cost of Fashion at Triangle Shirtwaist

It is convenient to take a closer look at another unfortunate disaster in our history, the Triangle Shirtwaist Company Fire. For North America, this was clearly a milestone event with respect to our collective attitude toward safety, and how this attitude can shift.

On Saturday, March 25, 1911, a disastrous fire erupted on the eighth floor of the 10-story Asch Building in New York City. The fire started on the premises of the Triangle Shirtwaist Company just as the workday was

ending. By the time this fire was extinguished several hours later, the top three floors were gutted, and 146 garment workers had perished either from the flames or by leaping from the top floors [6].

During the fire the adjacent streets were choked with a large crowd that witnessed this horrific scene. Further, this event also occurred at the height of the labor movement, and it became the tremendous catalyst that pushed the rallying cry of workers rights to new extremes. Public sentiment can best be characterized by the funeral parade that followed several days after the fire, where nearly half a million people attended the march despite a torrential downpour.

In the fire protection community, this fire was the turning point of the focus on safety, with safety for the community (i.e., mitigating citywide conflagrations) being overtaken by a new emphasis on the safety to life. Society was expressing itself that it was no longer acceptable for individuals to be injured or die in a setting like the workplace. This is a classic example of how safety is not simply a technical issue, but indeed it is inexplicably interwoven with social, political, economic, legal, and other agendas.

From a codes and standards perspective, the Triangle Shirtwaist Fire is a historical milestone because of the significant advances that arose from its ashes. While several individual's played a critical role in making this occur, one in particular is worthy of additional focus, Ms. Francis Perkins. Ms. Perkins was one of the individual's that stood in the crowd that tragic day and witnessed the Triangle Shirtwaist Fire. She eventually found herself as Secretary for the influential New York Committee on Safety, and at the NFPA Seventeenth Annual Meeting in May 1913 she was one of the keynote speakers.

The title of Ms. Perkins presentation was "The Social and Human Cost of Fire," and it evoked a stirring challenge to the NFPA to utilize its extensive network of public safety professionals to take action against such disasters [7]. From this was directly born the NFPA Safety to Life Project, responsible for NFPA 101, *Life Safety Code*®, that today is adopted and used in various forms by all 50 United States as well as numerous other governmental entities around the world [8].

Ms. Perkins would eventually become the first female cabinet member in the United States, when she was appointed Secretary of Labor under Franklin D. Roosevelt, and she held this office throughout FDR's entire four terms. The efforts of her and others have enabled far-reaching codes and standards activities like

the *Life Safety Code*. Clearly, safety in the workplace in the United States had shifted. The so-called unavoidable or unpreventable accidents, which in many cases were once considered the result of inscrutable decrees of Divine Providence, had instead become viewed as the result of unscrupulous greed or human improvidence, and this was simply unacceptable.

A Century of Developing the Tools for Safety

NIST's contribution in providing a technical and scientific foundation for our safety infrastructure over the last one hundred years has been impressive. As outlined in a presentation at the 1977 NFPA Annual Meeting by John W. Lyons, former NIST Director from 1990-1993 and member of the NFPA Board of Directors from 1978-1984, the NIST Center for Fire Research has been intimately involved in all facets of the codes, standards, and practices aspects of the fire problem [9].

Fire is a complex phenomenon, and when we speak of safety in the built environment, our efforts to deal with the fire phenomenon are typically our greatest challenge. For example, the science of fire must address issues such as characteristics of ignition, combustion properties of materials, toxicology of products of combustion, and human behavior during an emergency event. Several noteworthy topics where NIST efforts have contributed directly to advances in codes and standards include research on: fire suppression methods; characteristics of products and materials; smoke detectors; fire safety in health care facilities; and fire modeling.

An event of particular note and which was responsible for numerous significant advances was the Federal Fire Prevention and Control Act of 1974. This was triggered by the landmark government study known as "America Burning [10]." Then Secretary of Commerce Frederick B. Dent was one of the Commissioners of this report, and it provided direct enhancements to our safety infrastructure whose benefits are still being realized today.

Great strides have been made in developing the scientific tools to better understand this phenomenon, and NIST has been a clear leader in this effort. Yet certainly, there is still much work to be done. Despite our progress, death, injury, and destruction of property from fire in the United States and throughout the world remains today as a significant burden on civilization.

The Role of Safety in Today's Global Community

The Triangle Shirtwaist Fire provided a useful case study to exemplify how society can shift its perception of safety over time. However, safety is also dependent on the cultural attitudes that typically differ from one country to the next.

Another case study usefully portrays this concept. For 82 years, the world has recognized the Triangle Shirtwaist factory fire as the worst accidental loss-of-life industrial fire in which fatalities were limited to the building of origin. Then, on May 10, 1993, the Kader Toy Factory Fire in Thailand superseded this dubious recognition when 188 workers perished [11].

The details surrounding the Kader Fire have striking similarities to the Triangle Shirtwaist Fire. Today, Thailand is similar to other developing nations in that they are attempting to balance booming economic growth with workplace safety. Countries that are more developed, meanwhile, have a safety infrastructure that is likewise more established, and although disasters still occur, they generally do not have the grotesque violations of safety principles that are often seen in the nations that are coming-of-age. It is as if certain disasters must be experienced first-hand before their respective safety infrastructures can effectively address them.

When we speak of the safety infrastructure, it is more than simply well-written codes and standards, since achieving the ultimate goal of safety also requires adequate inspection and enforcement by the local authorities. With this and other reasons, it is clearly difficult to take a single prescriptive safety code or standard and apply it realistically in different countries, especially where concepts of safety vary. Enter the performance-based approach.

A true performance-based code has the flexibility to be used in any particular jurisdiction, and it is resilient to the local mindset of how "safe is safe." With flexibility to justify protection based on the available resources and the local societal risk tolerance, a performance-based approach delivers a controlled mechanism to realistically implement the latest state-of-the-art scientific tools (e.g., fire modeling).

Today, building codes around the world have been transitioning to a performance-based approach. The NFPA Life Safety Code mentioned earlier has a full performance-based option, and the new NFPA Building Code will likewise have such a performance-based option.

Challenges of Tomorrow

So what safety challenges do we face with tomorrow's built environment? Although the advances in safety techniques and scientific research will equip us well for the work ahead of us, the challenges themselves will likewise become more enhanced.

On the subject of technological advances, the smart building design of tomorrow is fast becoming a reality. With new building system protocol languages such as BACnet and Lonworks, the fire safety systems will soon be integrated with the building systems involving security, transport (e.g., elevators and lifts), environment (e.g., HVAC), and so on [12]. Such integrated buildings can be expected to function more efficiently, but they also present new challenges to assuring a safe and reliable building for both the occupants and emergency responders.

Meanwhile, today's world presents challenging safety applications that were unimaginable 100 years ago. For example, consider applications such as a genetic research laboratory, a jumbo aircraft manufacturing plant, or a facility handling high-powered lasers. Such applications raise the question of what the next 100 years will bring. For sake of discussion, consider the following unusual constraint of physical handicap that challenges today's safety professional. These are all real applications, each having required real innovative safety designs for fire and other hazards:

temperature extremes on an offshore oil drilling platform; lack of electrical interference in an anechoic chamber; highly purified air flow in a clean room facility; environmental containment for a genetic research laboratory; zero gravity in a space station; process purity in a molten salt bath; or oxygen enriched atmosphere in a space capsule simulator.

As we discuss the challenges of tomorrow's world, we can see that providing a safe environment is becoming more challenging for several reasons. Consider first, how *property value densities are approaching levels beyond rational comprehension*. Equipment that does more today is occupying a fraction of the space it used to. Certain facilities today have equipment with unimaginable property values per the area that it occupies.

One of the more extreme examples of the possible concentration of value was exemplified by the recent polyolefin manufacturing plant disaster in Pasadena,

Texas on October 23, 1989 [13]. A massive vapor cloud explosion that killed 23 workers and resulted in a dollar loss of an estimated \$750,000,000 (U.S. Dollars) destroyed this plant. With inflation taken into account, this single facility disaster was the fourth largest fire loss in U.S. history when it occurred, behind the San Francisco Earthquake of 1906, the Great Chicago Fire of 1871, and the Great Boston Fire of 1872. It raises the question of when we will see the first billion-dollar fire loss from a single facility.

Second, *certain facilities exhibit typically high levels of sensitivity to fire and smoke damage*. For instance, a moderately sized fire of a certain magnitude and smoke generation occurring in a sheet-metal machine shop would result in far greater damage if it instead occurred in a semiconductor clean room.

An incident that occurred in a telephone substation in Hawaii during 1982 exemplifies the sensitivity of today's high-tech equipment [14]. This small facility experienced a relatively small fire resulting in a high property value loss. The remote one story building was approximately 40 feet by 50 feet, and had no automatic fire protection systems protecting the several telephone terminal racks contained within. Following arrival by emergency responders, which was delayed by lack of telephone service, personnel quickly extinguished the fire using two carbon dioxide portable extinguishers and one dry chemical extinguisher. Despite a fire that was relatively small and easily extinguished, the dollar loss for this large-loss fire was set at \$2,300,000.

Third, *as technology becomes more advanced, society becomes more dependent upon this technology*. And as society becomes more dependent, it also becomes less tolerant of a loss. Consider the traditional indirect losses associated with a typical major disaster, such as loss of jobs, or loss of taxes to a community. Today, the indirect losses can be more far-reaching, with an impact on large segments of society.

Exemplifying this point is another incident involving a telephone switching station, though this time located in Illinois and occurring in May 1988 [15]. The estimated dollar value loss for this fire was \$50,000,000, but most significant was the indirect loss associated with lack of telephone service. Significant portions of the Chicago area were left with limited service for various periods of time. Community dysfunction included national reservation centers becoming disabled, O'Hare and Midway Airports being shutdown due to effects on the flight control system, a hospital complex losing all internal and external telephones, and various other tales

of how losing this technology affected many, many people.

Fourth, *new technologies create different and sometimes highly unusual hazards*. In contrast to the previous point that focused on society's suffering because of an event that took away something they depended on, this point is based on a disaster introducing a new and unusual hazard of some kind.

Consider the impact that arises when a minor crisis creates damage of little direct importance but is indirectly devastating because it unleashes a much greater hazard of another type. The nuclear facilities of the electric power industry provide an example of this thought, where the greatest impact can be damage to the safety or control mechanisms that prevent a radiation hazard. For example, in March of 1975 a serious fire occurred at the Browns Ferry Nuclear Power Plant in Alabama [16]. Even though no radiation was released from this seven hour cable fire, very significant concerns were raised afterwards over the possibility of a core meltdown in the nuclear reactor due to potential loss of reactor coolant. The societal ramifications of a core meltdown with radiation release, neither of which fortunately occurred, could have been immense.

Carrying this same thought further, some losses are devastating in terms of their primary effects rather than secondary effects. Today there exists an enhanced potential for extremely rapid hazard development on an unprecedented vast scale. For example, a fire in a rocket fuel manufacturing plant in Nevada during May 1988 resulted in an explosion that left a 400 foot crater and registered 3.2 on a Richter scale 200 miles away [17]. Of the estimated \$103,000,000 loss, \$27,000,000 was attributed to the originating facility and \$76,000,000 was based on damage to exposures. Another example was an explosion at a LP-Gas distribution plant just outside Mexico City that occurred in November of 1984 [18]. This tragic incident impacted a nearby residential neighborhood with over 500 deaths, 7,230 injuries, and 60,000 people displaced from their homes.

Although the incidents mentioned above are some of the more exotic examples of our brave new world gone awry, the challenges of safe design arise just as frequently in what are seemingly mundane occupancies, whether the physical complexities of a high-rise hotel atrium, security concerns at an airport terminal, or making built-in safety protection measures unseen at a museum. The lessons from the past provide stark recognition that the hazard applications of tomorrow demand special attention.

Welcoming a Second Century of Partnership

We have seen examples of how our interpretation of safety has changed over the last century, and how it inherently incorporates social, political, economic, and legal agendas into our efforts to provide technical conformity.

The positive impact upon society from safety documents and “codes” is often underestimated, and the resources and diligence required to develop and maintain these documents is, at best, daunting. How well do we appreciate, for example, the implications of the proposed ISO project on Occupational Health and Safety Management Systems, which continues to be considered and whose establishment seems imminent if current trends continue? The social and political agendas that are inherently part of the rights of workers are indeed profound, and these will undoubtedly be a factor in this activity.

To further illustrate this point, one industry-sector specific NFPA activity addressing Firefighter Occupational Health and Safety received over 22,000 public comments. Any foray into this arena should be expected to have high levels of interest and passion. We certainly want to raise the “level of safety” in industry-sectors or countries that are substandard, but under no conditions do we wish to simultaneously sacrifice the higher “level of safety” that certain constituents are fortunate to have already established. This is indeed a challenge.

Today, the majority of codes and standards addressing safety in the built environment, and especially fire safety, are shifting from pure prescriptive to now include a performance-based option. NFPA 101, *Life Safety Code*, mentioned earlier as one of the documents that resulted directly from the Triangle Shirtwaist Fire, recently underwent a complete transformation and its latest edition provides a useful example of a full performance-based approach.

Prescriptive-based documents can be traced back to the 19th century when major conflagrations created the need for specific building provisions. Revisions over the years resulted primarily from significant events that revealed deficiencies, and this has created codes based on empiricism and experience, rather than a scientific understanding of fire. Many scientific advances in safety have been made in recent times, but attempts to incorporate them into everyday practice are on-going. Performance-based codes and standards will promote freedom to develop appropriate and cost-effective building designs and bring safety to optimum levels.

NIST has played a crucial role in our current progress, and now their role only increases in importance. The research stability offered by NIST has contributed

greatly to today’s foundation of progress, and our direction toward performance-based documents speaks loudly toward the need for NIST’s contribution to make a fire safe tomorrow. Together, with NIST, we can succeed as we continue “putting safety first.”

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Putting Safety First




A Look from Yesterday to Tomorrow on the Building of Our Safety Infrastructure

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SLIDE 1

From Humble Beginnings


- **Life at the turn of the century**
 - The Industrial Revolution / Gilded Age
 - Tremendous growth in North America
- **NIST (NBS) created in 1901**
 - Coming of age of the safety infrastructure
 - Other organizations established



SLIDE 2

A Case Study in Partnership: The Great Baltimore Fire

- **The Great Baltimore Fire of 1904**
 - Sunday 7 February 1904
 - Destroyed 2,500 buildings; 80 city blocks
 - Burned 30 hours
 - Assistance from as far away as Philadelphia and NY City



SLIDE 3

A Case Study in Partnership: The Great Baltimore Fire


- **Problem:**
Lack of a common fire hose thread
- **NBS worked directly with NFPA**
 - Study of more than 600 different couplings from across U.S.
- **Progress in standardization**
 - Direct impact on city-wide conflagrations
 - Results still realized today



SLIDE 4

Lessons in the Value of Human Life


- **"Safety": What is it?**
 - Mentioned in important treaties and procedures
 - Not clearly defined
- **The concept of measuring the value of human life**



SLIDE 5

Lessons in the Value of Human Life

- **Concepts of "Safety"**
- **Balance of society's:**
 - Tolerance to risk
 - Willingness to commit resources
- **Example: Hi-Rise Sprinkler Systems**



SLIDE 6

The High Cost of Fashion at Triangle Shirtwaist

- **Asch Building: Triangle Shirtwaist Fire**
 - Saturday, 25 March 1911, in NY City
 - 10 story loft factory
 - Fire in top 3 floors
 - 146 fatalities, mostly young female garment workers



SLIDE 7

The High Cost of Fashion at Triangle Shirtwaist

- **Triangle Shirtwaist Fire:**
 - A milestone event in the advance of life safety
 - Focus from large scale conflagrations to safety of building occupants
- **Establishment of Code on Exit Drills:**
 - NFPA 101 Life Safety Code created



SLIDE 8

A Century of Developing the Tools for Safety

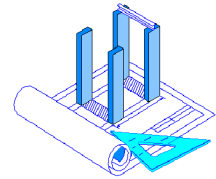
- **Development and implementation of the tools making the world a safer place**
 - Working together over the last 100 years
- **NIST's role in the safety infrastructure**
 - Federal Fire Prevention and Control Act of 1974



SLIDE 9

The Role of Safety in Today's Global Community

- **Case study comparison:**
 - The Kader Toy Factory & Triangle Fires
 - Yesterday (1911) vs. today (1993)
 - Developing vs. developed regions
- **How safety differs based on societal location and culture**



SLIDE 10

Challenges of Tomorrow

- **A changing landscape:**
 - The advent of smart building design
- **New challenges of extreme hazards:**
 - The high tech world of today & tomorrow
- **Facing the challenge:**
 - Future of prescriptive documents
 - Advantage of performance based approaches



SLIDE 11

Welcoming a Second Century of Partnership

- **Design tools for a better tomorrow**
 - Safety based on predicting building performance
- **Foundation for progress:**
 - Working together to make the world a safer place



SLIDE 12